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Basics
of Coating
Technology

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2000) driven the proportion of weight accounted for by plastics down to 18% (see figure 4.1.20). Agricultural and construction plant contains more and more nonload-bearing parts (linings and covers) made of plastic. All materials have to look the same on the product; this can be achieved with specially developed paints and coating processes.

The furniture industry is opting more and more for prefabricated and coated materials. Special mention should be made of the improvement of surfaces using foils, which are usually scaled with UV clearcoats.

Apart from the technological trends in the various industries there was a considerable shift in responsibilities for the item being coated during the 1990s. Owing to its high level of application know-how the coatings industry has, supported by appropriate contracts with its customers based on cost per m² or cost per coating unit, assumed more and more responsibility for the results obtained in coating the product. The pioneer in this area is the automotive industry, which restricts itself to planning, investing in and operating the coating lines. Technical implementation, quality monitoring and logistics of the lines are increasingly in the hands of paint companies.

7.1 Automotive OEM Coating

In scarcely any other sector of surface coating have the former manual and lengthy coating processes evolved into such high-tech, high speed industrial application processes as in the automotive industry. Whereas the coating of vehicles used to take days or even weeks, nowadays vehicle bodies pass through an entire coating line with all the cleaning stages, pretreatment, electrocoating and the usual two to four stages for applying the topcoat in approx. 6 to 10 hours.

This was necessary as well in order to cope with the continuous increase in the number of vehicles being manufactured. Global annual production of motor vehicles including trucks reached 57 million units in the year 2000. German manufacturers incl. Daimler Chrysler achieved a market share of 21% based on the worldwide production of German vehicle manufacturers. 5.5 million units were produced in Germany. The quantity of

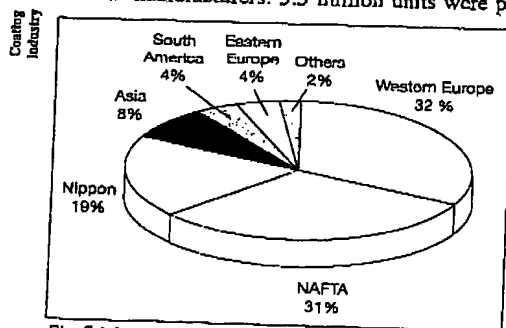


Fig. 7.1.1
Regional share of manufacturing cars (excl. heavy trucks)
of about 50 Mio units in 2000

paint required for this was approx. 140,000 t. The worldwide paint market for automotive coatings totals approx. 1 million t.

Development and introduction of new technologies are initiated not only by tasks brought about by economic necessity. Driving forces behind the development of paints and processes for coating vehicles include reduction in environmental pollution as well as qualitative improvement, e.g. in protection against corrosion and in durability, not to mention appear-

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ance. Special requirements are made with regard to resistance to chemical influences due to aggressive atmospheric substances and salt loads as well as physical properties such as adhesion and elasticity, and a high level of hardness. This now is valid for the global market of the car manufacturers [7.12.1].

One should bear in mind to what extreme stresses the vehicles are exposed throughout their service life. High temperatures, e.g. up to 70 °C, for dark colors in Florida and other regions as well as extremely low temperatures of down to -50 °C in the polar regions, constant temperature fluctuations of 10 - 20 °C a day, stone chip stresses on crushed-rock roads and unmade roads, high loads of salt in coastal regions and due to road salt in winter months, high ultraviolet radiation, the action of acid and alkaline exhaust fumes as well as physical stress in vehicle washing installations are factors which only constitute some of the many different burdens and actions which tend to damage coatings (see chapter 3.3.2).

It is easy to understand that such a catalogue of requirements cannot be met with a single coat of paint. For this reason well-coordinated paints are used which, when applied in several layers, handle various tasks within the requirements profile for the vehicles. Apart from the technical requirements made of a coating line there are organizational aspects such as process sequences and the paint supplier's responsibility for coating results which have become much more important [7.12.2]. This can be illustrated by taking a look at a cost analysis for the coating process. Of all the different types of cost such as capital investment, energy, staff, maintenance and paint, the latter only account for about 20% of the total cost block on average. If the cost of repairing defects or nonconforming surfaces is included in the overall analysis, crucial factors contributing to success and helping to ensure optimum coating results are on time deliveries of suitable quality paints to a well-designed coating line, and application conditions. These considerations prompted the automotive industry, together with the paint and coatings industry, to develop and increasingly implement exclusive supplier concepts and system supplier concepts.

The various substrates such as steel, galvanized steel and aluminium, as used nowadays in the manufacture of vehicle bodies, are first of all cleaned and then, in pretreatment, are provided with an inorganic conversion layer made of metal phosphates with a film thickness of about 1 - 2 µm. This step increases protection against corrosion and by enlarging the surface area it substantially improves the adhesion of the organic coating (see chapter 4.1). That is followed by the primer, usually by means of cathodic electrocoating for passive protection against corrosion. The average film thicknesses reach 20 - 22 µm on the outer surface and about 5 - 18 µm inside and in cavities. The primer surfacer that follows is designed to cover any unevenness in the substrate and thus create such smooth surfaces that they can serve as a base for a bright topcoat without

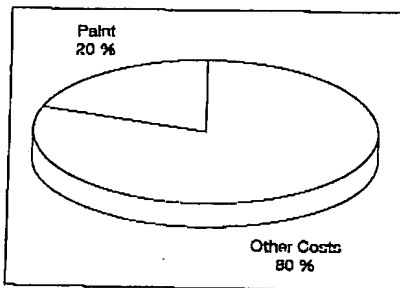


Fig. 7.1.2
Paint material cost as part of the total coatings cost

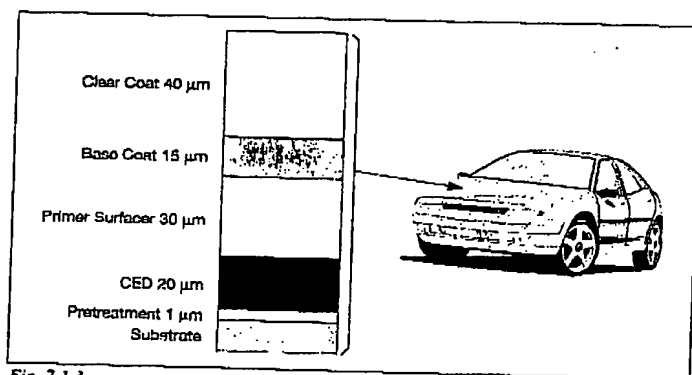


Fig. 7.1.3
Scheme of the multilayer coating of cars

the need for sanding. At the same time the primer surfacer fulfils the function of protection against stone chipping and has to provide anti-corrosive properties if, although it is rare, the electrocoat primer has been sanded through to the metal. The colored topcoat is usually applied in two steps "wet on wet" with a basecoat and clearcoat. "Wet on wet" means that the two coatings are applied in rapid succession without baking the basecoat so that they can be baked and crosslinked together. This topcoat system must then provide the correct color and a high appearance after interaction with the substrate and the other coating layers (see chapter 3.2.4).

In relation to the surface area of a standard vehicle body amounting to 70 m², which is covered by the electrocoat, and about 22 m² of external surface, which is covered by the topcoats, the average quantity of paint consumed is approx. 15 – 20 kg per body.

Application of cavity sealant, seam sealant and sound insulation is usually the responsibility of coaters. Seam sealant is applied after the electrocoat and it exploits the curing of primer surfacers for its solidification whilst cavity sealant is applied after the coating process. These process steps are necessary to ensure excellent protection against corrosion and acoustic comfort but they are unpopular with coaters on account of soiling (see chapter 6.2.7).

The starting point for the quality of coating in all requirements for protection against corrosion and the attractiveness of the surface is the conceptual design of the vehicle body. Coatability depends just as much on the shape and design of a vehicle as on the chemical and physical properties of the materials to be coated. Protection against corrosion and performance thus start on the design engineer's drawing board and in selection of the materials to be used. One must bear in mind that on the surfaces the various materials do not constitute homogeneous substances (see chapter 4.1).

The steel panels from various pre-refinement stages used for the automotive industry, e.g. pure steel, electrolytically galvanized (EG), hot-dip galvanized (HDG), pre-phosphated or also organically pre-coated as well as aluminium panels are subjected to various drawing processes and partially extreme deformations in the body-in-white shop, i.e. prior to the application of paint. A local difference in the levels of roughness is

therefore inevitable, i.e. between appearance, i.e. of the metal panel (see chapter 4.1), can only be compensated to a certain extent.

The length of a coating shop to delivery to finish considerably exceeded

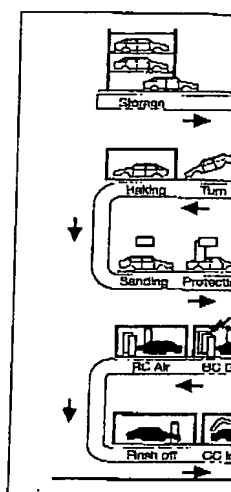


Fig. 7.1.4
Typical steps of a coating line

increase the first run ok, i.e. a vehicle body passes through the action and is accepted by the speeds of all lines on average 5 m per vehicle body above the paint shop is then achieved. Often prefer higher-speed lines. The environmental problem is becoming more and more efficiently solved. The paint sludge and is due to the terms of solvent emission, especially over the last 30 years. Apart from the coating unit, outlets via so-called air vessel, the size of which is

therefore inevitable. On the other hand, there is a direct proportional relationship between appearance, i.e. smoothness, build and gloss of the coating, and the roughness of the metal panel (see chapter 3.2.4 and 4.1.2). The substrate differences mentioned can only be compensated by the paint materials and the coating process to a certain extent.

The length of a coating line, from transfer of the vehicle bodies from the body-in-white shop to delivery to final assembly, is usually between 2 and 3 km. This can also be considerably exceeded if substantial time is spent on making corrections in order to

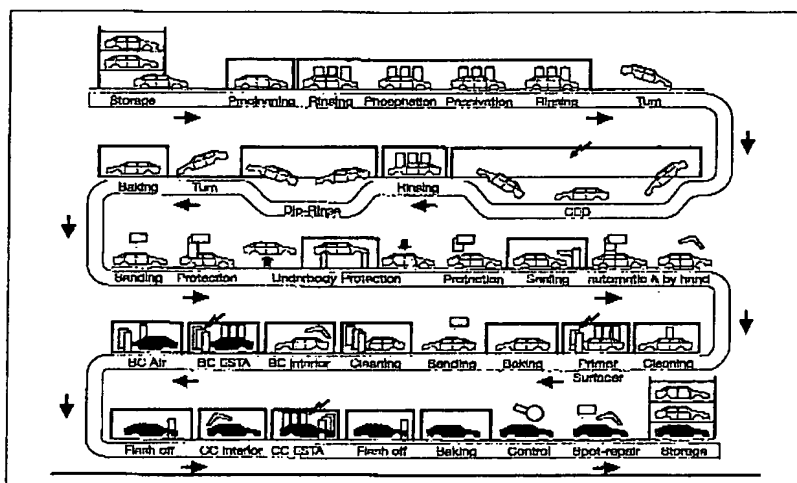


Fig. 7.1.4

Typical steps of a coating line in the automotive industry (BC = basecoat; CC = clearcoat)

increase the first run ok ratio or meet extreme line speeds. "First run ok" means that a vehicle body passes through the paint shop without the need for any major corrective action and is accepted by final assembly in accordance with the quality agreement. The speeds of all lines on average are between 3 and 6 m/min so for cycle lengths of approx. 5 m per vehicle body about 40 to 70 vehicle bodies are coated per hour. The dwell time in the paint shop is then about 8 – 11 hours. However, American vehicle manufacturers often prefer higher-speed lines of up to 12 m/min.

The environmental problems which have to be solved with coating lines that operate more and more efficiently involve solvent emissions and waste, which takes the form of paint sludge and is due to overspray when applying primer surfacer and topcoat. In terms of solvent emissions, paints have undergone substantial improvements, particularly over the last 30 years (see figure 5.3.3).

Apart from the coating units at all the stations paint has to be supplied to a large number of outlets via so-called circulation systems. Here the paint is pumped out of a supply vessel, the size of which is between 200 litres and 1,000 litres, circulated and thus fed to

the spray guns or spray bells (see chapter 4.2.1). The size of the supply vessels depends on outlet speed. For logistical reasons they are together in one room, the so-called "paint kitchen" or "paint mixing room", which has to meet the regional storage and safety regulations (see chapter 5.2.2). The tasks of paint kitchen staff are not only to supply paints but also to conduct quality control, keep documentation and support the process of localizing and avoiding defects.

To obtain a defect-free surface one endeavours to work under clean room conditions in the coating zones. Cleaning stages and corrective stages also have to be integrated into the sequence, depending on experience. Preventive measure to keep vehicle bodies and ambient conditions clean in paint shops are becoming increasingly important [7.12.3]. The spraying units are chiefly electrostatic high rotation atomizers which perform paint application with roof and side machines, the reciprocators. In special coating stages such as rocker panel coating, or when coating other areas where access is difficult, the pneumatic spray atomizer is used on robots.

High energy costs are incurred for ventilating the spray booths and in the curing ovens. The overspray due to spray application is fed to the flood sheet fluids under the installation through air ducts in the spray booths. The water is treated in reasonable cycles and coagulated paint is removed (see chapter 4.2.1).

Any necessary repairs to defective spots in the surface of the coating are performed by ejecting the vehicle body in booths with so-called spot repair equipment. In the event of any major defects or a large number of defects the vehicle body is usually repaired by running through the coating line again.

7.1.1 Pretreatment

In the body-in-white shop special attention is paid to the type of anticorrosion oils and drawing greases used which penetrate voids and grooves formed on the body panels by the drawing process. Their ability to be easily removed in pretreatment baths and a good level of compatibility with the paints improve the efficiency of coating lines substantially.

Pretreatment of the vehicle bodies delivered from the body-in-white shop to the paint shop is organized by the various vehicle manufacturers in different ways. In some cases the cleaning process is the responsibility of the body-in-white shop and in others it is the full responsibility of the coaters. At all events the sequence of pretreatment consists of the following stages: cleaning, phosphating and rinsing.

Cleaning and phosphating are chiefly performed in dip baths, the size of which depends on the number of vehicle bodies/h. At quantities of less than 15/h cycle tanks are used, otherwise continuous baths with a capacity of 150 to 450 m³.

To avoid bubbles of air in the interior and cavities on continuous lines tilting motions are performed inside the baths by routing the conveyor belt accordingly. Recently new concepts have been used incorporating rotary motions during passage through the line. In the form of the "Rodip" processes [7.12.4].

Cleaning

In practice, a weakly alkaline degreasing solution of aqueous mixtures consisting of salts, wetting agents and emulsifiers has become standard. The application temperatures are 40 °C, and up to 60 °C in individual cases (see chapter 4.1.2). The process is usually

a combination of water in order to and anticorrosion throughput times. The cleanliness of operate efficiently body passing thr

Phosphating

Phosphating is a: the aspects of cc the conversion of about 1 – 2 µm t portant factor quality of the whole. It takes stages, firstly ac surface and sect of the conversi form of phosph Modern materi ability to treat strates like steel, aluminium sium jointly to a In particular, t proportion acc aluminium atta for greater attent was about 1.1% forecast for 200: On the usually l owing to the pre process control, ment materials [The state of th manganese. The accelerators con they are being i well as peroxid chapter 4.1.2). With respect to phosphating zon rinsed off. That substances on t electrocoating f

a combination of spray and dip treatments followed by rinsing stages with deionized water in order to avoid salt residues. The dip stage allows optimum cleaning of drawing and anticorrosion oils as well as good cleaning of the internal areas but it calls for longer throughput times than with spray cleaning.

The cleanliness of the entire vehicle body is essential to ensure that the coating lines operate efficiently. By efficiency we mean the so-called "first run ok ratio" of a vehicle body passing through the entire line without the need for significant corrective action.

Phosphating

Phosphating is an important stage for increasing the durability of a body coating under the aspects of corrosion protection and adhesion. The uniformity of the application of the conversion coat, which is

about 1 – 2 μm thick, is an important factor affecting the quality of the coatings as a whole. It takes place in two stages, firstly activation of the surface and secondly build-up of the conversion coat in the form of phosphate crystals. Modern materials have the ability to treat different substrates like steel, galvanized steel, aluminium and magnesium jointly to a limited extent.

In particular, the increasing proportion accounted for by aluminium attachments calls for greater attention. The figure was about 1.1% in the year 2000 in relation to the total surface area of vehicles and the forecast for 2005 is 1.5% [7.12.5].

On the usually horizontal continuous lines the high quantity of sludge which occurs owing to the pretreatment of aluminium makes it necessary to conduct more stringent process control, more intensive rinsing at bath exit and a specific adaptation of pretreatment materials [7.12.6].

The state of the art nowadays includes zinc phosphating processes containing manganese. They have superseded ones containing nickel. Furthermore, less and less accelerators containing nitrates and nitrites for activating the surface are being used; they are being replaced by environmentally compatible active amino compounds as well as peroxides. In the case of aluminium substrates fluorides are also used (see chapter 4.1.2).

With respect to the ensuing electrocoating process the rinsing zones downline of the phosphating zones are sized so that as much of the phosphating solutions as possible is rinsed off. That minimizes contamination of the electrocoating bath by salts or other substances on the one hand, and on the other, flaws are avoided in the deposited electrocoating film which may be caused by salt residues on the surface of the

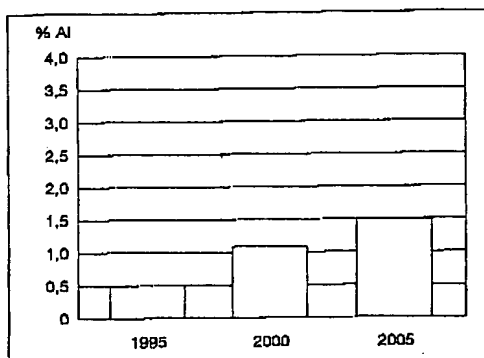


Fig. 7.1.5
Growth of the relative share of aluminium on automotive body construction

workpiece. This is particularly necessary with even surfaces where the appearance has to meet high standards.

In some cases there is also a so-called passivation zone upline of the rinsing zones. This improves the adhesion and corrosion protection properties of the electrocoat primer. The materials containing chromium used in the 1980s have nowadays been replaced by environmentally compatible, toxicologically safer chromium-free products such as titanates. Very often passivation steps are already abandoned.

After the last rinsing cycle, which is conducted with deionized water, it is advisable to install a hot blow zone with air temperatures of between 50 °C and 60 °C in order to completely dry the surface of the workpiece. Otherwise there is a risk of marks appearing during immersion into the electrocoating bath under tension, which would lead to considerable sanding work on the coated object.

Over the last few years the dip coating process has become more common than spraying. The better development of conversion layers in cavities proved to be the deciding factor. So-called slipper-dip processes combine dipping and spraying by immersing the vehicle body up to the waistline and spraying the upper section. The advantage is that the tanks are smaller and hence easier to control. For space reasons the Vertak process was used for some time. Here the vehicle bodies are dipped vertically into several cycle baths at each stage and treated. The "Rodip" process can also be performed as a cycle process by rotating the vehicle body into the bath in order to finally pretreat it horizontally, albeit upside down. In this process the advantages are that the visible surface to be coated is not contaminated by any sediments from the baths.

Owing to the large number of treatment steps, not least on account of the high demands in terms of vehicle body cleanliness when immersing it in the downline e-coat bath, the size of pretreatment lines is astonishing. Depending on the configuration there can be tunnels up to 200 m long made of stainless steel sheet, through which a vehicle body has to pass. The effluent of a pretreatment line requires careful attention, although it can usually be disposed of in the normal sewage treatment plants.

7.1.2 Electrocoating

Coating
Industry

Nowadays electrocoating has become the most widespread process for evenly applying a corrosion protection primer to all metal mass-produced products such as vehicles (see chapter 4.2.1). Consequently, practically all vehicles throughout the world are primed by the electrocoating process.

Anodic electrocoating introduced at the end of the 1960s was a revolutionary process for parts of complex design with major advantages of improved utilization of paint and hence improved economy and environmental friendliness compared to the dip processes used up to that point in time. This was substantially improved once again by introducing the ultrafiltration technique. The ultrafiltrate produced in ultrafiltration installations is used as a rinsing medium in a counter-current system in order to wash off the electrocoat clinging to the surface and return it to the tank. In this way material efficiencies of over 98% are achieved.

The chemical basis of the first anodic primers was maleinized linseed oil, which was later replaced by maleinized polybutadiene. They were self-curing binders which were hardened with the aid of catalysts at approx. 160 °C. Then, in the middle of the 1970s

Parameter
Solids
Solvents
Film thickness
Lead
pH
Bath temperature
Deposition rate
Voltage
Electrical energy

Fig. 7.1.6
Technical

the anodic process remained very low. The reasons for this are:

- 3 - 4% of the total weight of the vehicle body is lost during the pretreatment process.
- Much of the paint is lost during the dipping process.
- Greater consistency and graininess of the paint.
- Smaller tanks and higher design costs.

These advantages are not realized in all cases for the homogeneous vehicle body. The anodic process places high demands on the analytical control of the bath content. A mentioned two-component process is becoming a system via

Parameter	Unit (conditions)	Anodic ED 1965	Anodic ED 1975	Cathodic ED 1975	Cathodic ED 2000
Solids	(1 h/130 °C)	8 – 15 %	12 – 18 %	15 – 20 %	15 – 20 %
Solvents in tank	%	10 – 15	5 – 10	3 – 5	0,5 – 2
Film thickness	µm	30 – 40	25 – 35	15 – 20	18 – 22
Lead	Yes/No	Y	Y	Y	N
pH		7 – 9	7 – 9	6 – 8	5 – 7
Bath temperature	°C	20 – 25	20 – 25	25 – 30	28 – 35
Deposition time	S	120 – 200	120 – 200	120 – 200	120 – 200
Voltage	V	150 – 250	150 – 250	250 – 350	300 – 450
Electr. equivalent	mg/C	60 – 80	50 – 70	30 – 50	30 – 40

Fig. 7.1.6

Technical data of product generations for electrodeposition (ED) coatings

the anodic systems were superseded by cathodic electrocoats and the latter have remained state-of-the-art to the present day. The latest generations are characterized by very low solvent contents, no lead and a high level of reliability.

The reasons for the rapid switch from anodic to cathodic electrocoats despite conversions costing several millions of euros were as follows:

- 3 – 4 times better protection against corrosion in conjunction with a suitable pretreatment on steel, prevention of iron dissolving and enhanced crosslinking by new film forming agents
- Much improved throwing power, i.e. better coating of cavities like in rocker panels
- Greater process reliability due to compensation with two components made consisting of neutralized and pre-dispersed binder as well as a pigment concentrate and greater chemical stability of the components in water
- Smaller film thicknesses
- Greater alkaline resistance of the film at the points of contact in zinc/iron hybrid designs

These advantages are of various significance depending on the industrial application. In all cases process reliability plays a crucial role because for industrial mass production the homogeneity of the products used is vital. Since a coating line handles up to 1,500 vehicle bodies a day with an area of approx. 60 – 90 m² to be coated by each unit, this places high demands on formulation and production of the coating materials. That also applies to process control and plant engineering at the user's. Both physical and analytical parameters serve as control criteria in order to always keep the electrocoat bath at the same level of quality with regard to coating results. Nowadays there are control circuits based on power consumption, e.g. in order to maintain the bath solid content. Another important contribution to process reliability has been made by the mentioned subsequent adding of fully neutralized coating material and the splitting into two components. The subsequent feed of already dispersed material means that this process is simplified by reducing it to simple addition. However, the nonseparated acid becomes concentrated during the process in the tank and has to be withdrawn from the system via an anolyte circuit (see chapter 4.2.1).

Coating
industry

Improvement in the corrosion protection of the cathodic electrocoats in comparison to the anodic ones can be verified by conducting various tests.

Depending on the quantity of items per hour the tanks operate in a cyclic or continuous system, in a similar way to pretreatment. Cyclic systems achieve tank capacities of 100 m³ whilst continuous systems achieve up to 450 m³.

Properties/Tests	Unit	Anodic 1975	Cathodic 2000
Film thickness	µm	30	20
Salt spray test ASTM B117 (480 h)	mm ¹	2	0
Climate change test VDA 821 (10 cycles)	mm ¹	destroyed	< 2
¹ rust creepage			

Fig. 7.1.7

Comparison of corrosion protection anodic versus cathodic electrodeposition coatings on zincphosphated steel panel as rusting at the scribe

The actual electrocoating process commences upon transfer from pretreatment [7.12.7]. The vehicle body can be wet or dry when it is dipped into the tank. With cyclic systems a variable voltage programme can be set with one rectifier in order to achieve optimum coating results in terms of surface quality, film thicknesses and throwing power. In the case of continuous systems the voltage programme is set with at least two rectifiers. The input rail is separated from the main rail for the central dipping area and the emerging zone. This is necessary in order to reduce high current peaks which can cause surface defects on account of high local heat development and excessive gas development (see chapter 4.2.1 and 6.2.2).

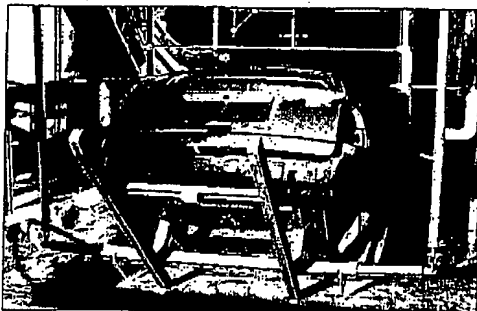


Fig. 7.1.8

Dipping a body into the electrodeposition tank

vent the pigmented electrocoats from settling the bath contents must be circulated continuously. As a rough guide when sizing the pumps one should aim for circulation of about five times per hour (see chapter 4.2.1).

In many coating shops in the automotive industry there is now only one tank supplying a number of topcoat lines owing to the reliability of the electrocoating process. In this way it is possible to prime up to 1,500 units a day. At such a throughput it becomes particularly important to regularly compensate with replenishing material in order to

achieve a consistent consumption is paid.

Bath material still cation and adhering by rinsing. Since the current method will be returned to the coating stage with a modern electrocoating rinsing stage with a spraying cycle, should be moved afterwards to an overall set-up of zones take the form < 0.6% solids these rinsing (see figure conditions).

Deposition of the electrocoat in the baking oven. There removed and good protection film. Bath 190 °C for a least 1 linking process organic. To comply with modern view of both aspects which are usually organic. An electrocoating process environmental pollution four sources of emissions:

1. Emission of volatile organic compounds
 2. Emission of organic solvents
 3. Waste water in the effluent
 4. Anolyte overflow
- The solvent content 0.5%. Together with ovens, this causes a maximum allowable then treated by thermal crosslinking reaction. Quantities of ultrafine the sewage treatment and decomposition to

achieve a consistent level of quality. The automatic subsequent addition linked to power consumption is particularly expedient for this (see chapter 4.2.1).

Bath material still clings to the film compacted by electro-osmotic effects during precipitation and adhering firmly to the substrate when exiting the tank and it has to be removed by rinsing. Since this material can still be used, the vehicle body is rinsed by the counter-current method with the ultrafiltrate produced from the tank and the rinsing water is returned to the coating bath (see chapter 4.2.1). This takes place in at least two cascades. Modern electrocoats no longer require any further rinsing with deionized water after the rinsing stage with pure ultrafiltrate.

When designing the rinsing zones care must be taken to ensure that paint is prevented from drying onto the coated object. The first rinsing process, usually conducted with a spraying cycle, should therefore be completed by the vehicle body in less than one minute after emerging from the tank. Once paint runs have dried on they can only be removed afterwards by sanding and they otherwise lead to considerable disruptions in the overall set-up of vehicle coating. In a similar way to pretreatment the main rinsing zones take the form of dip tanks. Depending on the quantity of ultrafiltrate fed in with < 0.6% solids these baths have solid contents of less than 1% in order to ensure efficient rinsing (see figure 4.2.19). Material efficiencies of over 99% are achieved under such conditions.

Deposition of the electrocoat and the rinsing process are followed by a pass through the baking oven. There the residual water of approx. 5% present in the coating is first of all removed and good flow is achieved along with crosslinking to create the corrosion protection film. Baking takes place at an object temperature of between 160 °C and 190 °C for at least 15 minutes depending on the type of electrocoat. During the crosslinking process organic substances are released which can lead to deposits in the oven. To comply with most legal regulations they have to be sent for thermal after-burning. In view of both aspects an optimum supply and circulation of air must be set in the ovens, which are usually of type A design (see chapter 4.3.1).

An electrocoating process can be chiefly used in a closed circuit without any significant environmental pollution due to waste materials. In terms of environmental pollution four sources of emissions have to be taken into consideration:

1. Emission of volatile compounds in the tank and rinsing zone areas
2. Emission of organic compounds in the oven due to crosslinking reaction and increased paint film temperature
3. Waste water in the form of ultrafiltrate of rinsing water
4. Anolyte overflow with organic acids.

The solvent contents of the latest generation of cathodic bath material are less than 0.5%. Together with the usual air ducting via the tank, which is directed into the baking ovens, this causes the concentration of organic compounds to be below the 'MAC' maximum allowable concentrations at the workplace. The air with the minimal load is then treated by thermal after-burning together with the cleavage products from the crosslinking reaction in the baking ovens.

Quantities of ultrafiltrate that have to be disposed of occasionally can be fed directly to the sewage treatment plants because the biodegradability of the composition is perfect and decomposition takes place in relatively short dwell times. The same applies to the

substances in the anolyte circuit. Here one has to consider that the pH is about 4, whilst the ultrafiltrate is within the working range of the electrocoat, i.e. 5.8. Before the primed vehicle body is transferred to the next station, the surface is inspected and repair steps may have to take place, usually in the form of sanding defective surfaces. To reduce the level of dirt and dust caused by such sanding operations it is recommended that sanding be conducted by the wet method. Apart from that, there has to be a very careful cleaning procedure prior to application of the primer surfacer.

7.1.3 Seam Sealant and Underbody Protection

In most paint shops the vehicle body is sealed with sealing materials when electrocoating has been completed and provided with underbody protection materials. In individual cases soundproofing materials are also inserted at this stage of the coating process. The electrocoat primer is a suitable substrate for the materials made of plastisols (e.g. PVC or PUR). Sealing materials considerably improve the protection against corrosion in cavities with poor accessibility for CED, whilst the underbody protection coating of approx. 1 mm film thickness protects against stone chipping. In many cases underbody protection coating has meanwhile been replaced by plastic panels because application of these materials involves considerable contamination of the coated surface and the efficiency of the paint shop declines.

Application of seam sealant is performed with airless spray guns at high temperature with the aid of robots (see chapter 4.2.1). Manual adjustments may still be necessary in individual cases if the seams do not always have the same gap width and if the seam has to be coated where there are awkward joints with several body parts.

Application of the underbody protection coating is also performed by the airless method with the vehicle body jacked up. In this case the precision of the spray jet is higher and manual corrections are rarely necessary.

The pieces of soundproofing material are chiefly inserted by hand.

They are thermally treated together with the seam sealing and underbody protection materials in the downline primer surfacer oven. In the case of PVC the emulsion particles become dissolved in the plasticizer. When it has cooled down the material gels to form a film, which is highly resistant to physical stress caused by abrasion and stone chipping. For quite a while some automotive manufacturers also used to provide the visible exterior of the vehicle body with special stone chipping protection coatings or plastisols in the lower area, e.g. at the door sill or front spoiler. Modern primer materials have now made the use of such materials superfluous.

7.1.4 Primer Surfacer

As opposed to electrocoating the primer is essentially applied by spraying to the exterior. In the entrance area of vehicle bodies, in the engine and luggage compartments. As a result the vehicle body is given its second external coating, which not only provides extra corrosion protection and stone chipping protection and protects the electrocoating from possible attacks due to ultraviolet radiation but also serves as further preparation for a smooth surface and a bright coating.

Owing to their multi-functionality the formulation of primer surfacer is a difficult task. Nowadays polyurethane-modified polyesters in conjunction with epoxy resins have

become the most popular. They are rounded off with crosslinkers. They are chiefly aqueous coatings with high pigment content. Consequently the pigment ratio is between 1:1 and 1:2. The world average is coated with 0.1 mm and a high material efficiency. Technical and ecological alternatives are being developed. At a film thickness of approx. 150 µm the object temperature is 130 °C for the liquid one. As the name says, primer is in order to level the substrate, build good sandability in coating lines is to make the levelling of substrate more different substrates to get a homogeneous appearance. Over the last few years account of the aspect of color of the primer surface. Companies have decided in favour of 3 and 7 primer surfacers applied, depending on the minimum basecoat. They have developed this further to create each basecoat is based on. Whereas in the above analysis on the one hand, this intertechnological properties protection of the substrate electrocoating, the primer. To prepare application of primer to a cleaning process. In completed with an automatic the surface is conducted with seam sealant resulting from cleaning systems have rotated to prevent any electrostatic measures serve to achieve. On some coating lines the precision air ducting. Air dust easily be separated off.

become the most popular film forming agents. The appropriate coating formulations are rounded off with crosslinkers based on melamine or blocked isocyanate. In Europe they are chiefly aqueous coating materials and are generally characterized by a high level of pigmentation. Consequently the solid content is between 50% and 65% and the binder/pigment ratio is between 1 and 0.5. Approx. 10% of all vehicle bodies throughout the world are coated with powder primer surfacer nowadays. With a film thickness of 0.1 mm and a high material yield due to recycling at the line they constitute an economical and ecological alternative to aqueous primers, which already fulfil all their functions at a film thickness of about 25 μm . With most formulations the crosslinking conditions are $> 150^\circ\text{C}$ object temperature over a period of 15 minutes but they can be about 130°C for the liquid ones.

As the name says, primer surfacer have the task of filling out and smoothing unevenness in order to level the substrate for the following layers of topcoat. Apart from the good build, good sandability is another important quality criterion even the goal of modern coating lines is to make the sanding of primer surfacer superfluous. On the other hand, the levelling of substrates has become more important nowadays because more and more different substrates such as steel, galvanized steel, aluminium and plastics have to get a homogeneous appearance on the vehicle body despite the fact that there are considerable differences in surface properties in some cases.

Over the last few years special attention has been devoted to the primer surfacer on account of the aspect of the hiding power of the colored topcoats. Consequently, the color of the primer surfacer is extremely important in order to minimize the film thicknesses of the next basecoats for any given range of topcoat colors. Many vehicle companies have decided in favour of the "color keyed primer surfacer" concept. Here between 3 and 7 primer surfacer colors are supplied to the spray booths, which are then applied, depending on the color of basecoat, in order to achieve maximum color agreement and minimum basecoat film thickness. Some automotive manufacturers have developed this further to create a so-called "color specific primer surfacer" concept in which each basecoat is based on a specific primer surfacer whose color is largely identical.

Whereas in the above analysis the emphasis is on the visual quality of the primer surfacer on the one hand, this intermediate layer has to fulfil crucial tasks in the area of physical/technological properties such as stone chipping protection on the other. Wherever protection of the substrate against corrosion is missing, e.g. after sanding through the electrocoating, the primer surfacer also has to fulfil corrosion protection functions.

To prepare application of primer surfacers the vehicle body is, in many cases, subjected to a cleaning process. In most cases this is first performed manually and is often completed with an automatic process similar to that of a car wash. Manual cleaning of the surface is conducted with special, lint-free and usually moist wiping cloths. Any seam sealant resulting from improper application also has to be removed. The automatic cleaning systems have rotary brushes which are provided with ostrich feathers in order to prevent any electrostatic charges and any accumulations of dirt caused thereby. All the measures serve to achieve as high a first-time ratio as possible (see figure 7.1.9). On some coating lines the surface of the body is cleaned with air from air locks and precision air ducting. Air ducting is designed in such a way that the particles of dirt can easily be separated off.

Coating
Industry

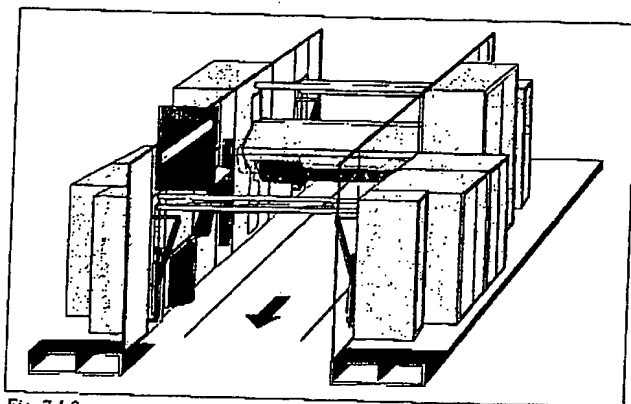


Fig. 7.1.9
Scheme of an automated cleaning station for preparing defect-free coatings in automotive painting process

Liquid paints can be applied to the body of the vehicle with the aid of an appropriate number of supply lines, the circulation system, without any substantial loss of material, via a spraying assembly. The circulation system is supplied from a central supply tank which usually has a refill tank. In the latter the coating material is adjusted to set viscosity levels as required. The circulation system pipes, which can be up to several hundreds of metres in length, are supplied from the supply tanks. The excess material not consumed flows back into the tank via a back pressure regulating valve. At the outlets of the approx. 7 to 10 spraying units per coating line there are pressure controllers which ensure that material pressure at the outlets remains consistent in order to achieve uniform film thicknesses. Owing to the rheologically more demanding aqueous coating materials volume forced systems have now largely superseded the pressure-controlled systems (see chapter. 4.2.1).

Whilst coatings used to be applied with compressed air, state-of-the-art application uses electrostatically assisted high-rotation atomizers. The necessary number of spray units largely depends on line speed and the film thickness of usually aqueous primer surfacers to be applied. To reach points with poor accessibility such as the door rocker panel in the interior, the first stage of the coating process usually consists of two robots with pneumatically atomizing spray units. For each one these are usually followed by two side machines and two roof machines (reciprocators) for overall coating. The spray jets of the latter can be programmed in such a way that they optimally follow the contours in order to ensure a uniform film thickness. When only one color is used internal charging has proved successful whilst if more than one color is being used external charging is more favourable in terms of the volume of investment. The two methods have slightly different levels of transfer efficiency, with external charging not quite so good. Cleaning the spray booths is one of the important factors helping to achieve high first-time ratios. The frequency and the economy of overspray recovery from booth water [7.12.8] depend on the transfer efficiency which has to be achieved.

The environmentally beginning of the 199 primer. The large film high level of transfer system, plus the low: for the gradual increa USA were implement In 2001 about 3.5 mil vehicles sector some ized cabs of commerc with powder and disp electrocoating. The switch in dispens ment, different handli der coatings compare coating materials on a and the problems v changes are reasons v tration of the automot try by powder coating ogy has so far only be For the application c primers as well it is im take the same amoun when cleaning the vehi The low volumetric flo the number of spray u order to apply the pow electrostatically assiste reach 60% depending c designed carefully. This ducting and a high degr in the underbody area a recovered which is mai efficiencies of > 98%. 80 – 100 µm are just as they present less "orange In the case of aqueous or cation zone it reaches the on the type of coating a major role when ensurin the oven, passing throu surface the vehicle body aqueous primer surfacer "wet on wet" process, is,

The environmentally-friendly and eco-efficient powder coating was first used at the beginning of the 1990s for primer surfacer with a preliminary stage as stone chipping primer. The large film thickness for good stone chipping protection, nonuse of solvents, high level of transfer efficiency by recycling the overspray directly in the application system, plus the lower cost of investment and lower running costs were the main reasons for the gradual increase in the use of powder primer surfacers. Initial applications in the USA were implemented not least on account of legislation [7.12.9].

In 2001 about 3.5 million vehicles were coated with powder primer. In the commercial vehicles sector some manufacturers have switched to now only priming the all-galvanized cabs of commercial vehicles with powder and dispensing with electrocoating.

The switch in dispensing equipment, different handling of powder coatings compared to liquid coating materials on a large scale and the problems with color changes are reasons why penetration of the automotive industry by powder coating technology has so far only been slow.

For the application of powder primers as well it is important to take the same amount of care

when cleaning the vehicle body to be coated as when applying aqueous primers.

The low volumetric flow of powder and the large film thickness call for about double the number of spray units compared with liquid paints. The highest delivery rates in order to apply the powder with as high a transfer efficiency as possible reach those of electrostatically assisted rotary atomizers. The levels of first transfer efficiency only reach 60% depending on the type of body, so for recycling powder the cab has to be designed carefully. This involves suitable conveyance of the vehicle body, efficient air ducting and a high degree of cleanliness. In the case of primers larger film thicknesses in the underbody area are frequently used for reasons of quality. There it is the powder recovered which is mainly used. That way it is possible to achieve material transfer efficiencies of > 98%. The surfaces of powder layers with thicknesses of approx. 80 – 100 μm are just as good as with liquid coatings but they have the advantage that they present less "orange peel" on vertical surfaces but more on horizontal surfaces.

In the case of aqueous or solventborne primer surfacer, when the body has left the application zone it reaches the baking oven via a flash-off zone. Sizing of the ovens depends on the type of coating applied, the object and line speed. The heating curve plays a major role when ensuring defect-free, smooth surfaces (see chapter 4.3). After leaving the oven, passing through the sanding and correction zone and repeated cleaning of the surface the vehicle body passes into the topcoat application zone. The application of aqueous primer surfacer with aqueous basecoats without prior baking, that is, by the "wet on wet" process, is gaining importance [7.12.10].



Fig. 7.1.10
Application of powder primer surfacer in automotive painting

7.1.5 Topcoat Application

Suitably high demands are made of the last coating layer, which determines the visual impression of the vehicle throughout its service life and which is subjected to enormous stresses in all parts of the world during that period. By interacting with the coating design as a whole the topcoat helps guarantee the standard of physical properties of the coating. Good adhesion between all coating layers and with the substrate, a harmonized level of formability and elasticity whilst providing the film surface with a high level of hardness are worthy of special mention. High gloss, good flow, resistance to ultraviolet radiation in combination with weather influences, resistance to chemicals and organic solvents such as fuels, are the requirements which a topcoat has to fulfil (see chapter 3.2 and 3.3).

At the same time it is the topcoat which provides the color. Under the conditions described it must guarantee a high level of surface uniformity, repair capability at the coating line and, during use of the vehicle and over the service life of the vehicle, consistency with regard to the visual and physical/technological properties.

Color styling nowadays plays a much more important role than about 20 years ago. This is evident from the fact that meanwhile entire departments of automotive manufacturers and coating manufacturers monitor color trends, develop new colors and special effects, and select them carefully for new models [7.12.11]. The regional aspects of the world of colors have gained profile. For example, the color frequencies in the three regions of North America, Asia and Europe are quite different in the year 2000 [7.12.12]. The importance of color styling is also supported technologically, on the one hand by new



Fig. 7.1.11
Example of a design supporting coating

application processes and by new raw materials and pigments, on the other, which have created enormous scope for color variations. To satisfy the requirements described more fully there has been a considerable change in coating materials and application processes over the last 20 years. For instance, the topcoat is applied in two separate layers almost everywhere nowadays, by the "wet on wet" process. Consequently the two functions have been separated, i.e. color in the first coat and resistance in the

second coat, the clearcoat. The paint formulations for both coats have been optimized in order to fulfil the functions described to such an extent that levels of resistance lasting over 10 years have been achieved, e.g. in gloss and color. An important formulation step was not only the use of UV-resistant acrylic resins but also the use of UV absorbers and at the end of the 1970s as well as development of pigments with a higher level of light fastness (see chapter 2.1.3).

With this two-layer system, consequently, light hitherto unknown topcoats has led to coats. That made customers' wishes Experts refer to coat (CC).

Basecoat Solventborne has. in North America The resulting high extent in North A

Metallic
Solid color
Total (%)
(1) Metallic/Solid c

Fig. 7.1.12
Reduction of organic a

common. Compare approx. 16%. Depend on dry film thickness. Before reaching the precoated with the sill and some zone the engine compartment and of the luggage compartment. In case of robot application the vehicle body usually stopped briefly in so-called "stop go" mode and the appropriate hoods, doors are opened that coating can take place automatically. This may have to be repeated for clearcoat application. If appli

With this two-layer topcoat it was also possible to create much brighter metal effects. Consequently, light/dark effects were achieved depending on the angle of view, as were hitherto unknown with single-layer topcoats. The entire quality level of such two-layer topcoats has led to the fact that the single-layer solid colors today are also applied in two coats. That made it possible to set up standardized coating lines which can meet customers' wishes more easily, irrespective of the popularity of various colors. Experts refer to the first layer as the basecoat (BC) and the next layer as the clearcoat (CC).

Basecoat

Solventborne basecoat is a low-solid paint which can reach 45% solids for solid colors in North America and 35% solids in other countries. The effect coatings are much lower. The resulting high solvent emission has led to the fact that in Europe and to a certain extent in North America as well aqueous formulations of coating materials have become

		Solventborne BC	Waterborne BC
Metallic	NV	25 %	25 %
	Solvents/NV	3,0	0,5
Solid color	NV	40 %	35 %
	Solvents/NV	1,5	0,3
Total ⁽¹⁾	Solvents/NV	2,5	0,4

(1) Metallic/Solid color = 60:40

Fig. 7.1.12

Reduction of organic solvents by waterborne basecoats (BC) related to the nonvolatiles (NV)

common. Compared to the solventborne basecoats they only have a solvent content of approx. 16%. Depending on color, basecoats are applied in films of approx. 12 to 30 µm dry film thickness.

Before reaching the automatic coating machines such areas as are difficult to access are precoated with the aid of robots or by hand pneumatically. These include the doors

sill and some zones of the engine compartment and of the luggage compartment. In the case of robot application the vehicle body is usually stopped briefly in so-called "stop and go" mode and the appropriate hoods and doors are opened so that coating can take place automatically. This may have to be repeated for clearcoat application. If applied

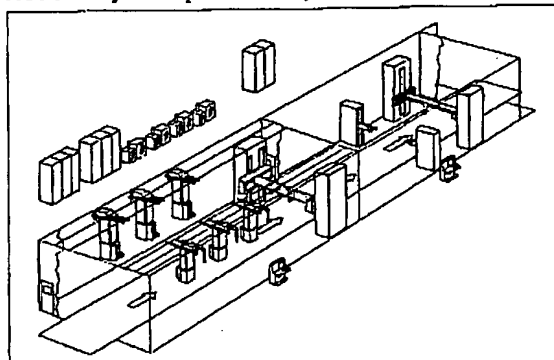


Fig. 7.1.13

Typical placement of bells for roof machines and side machines

Coating
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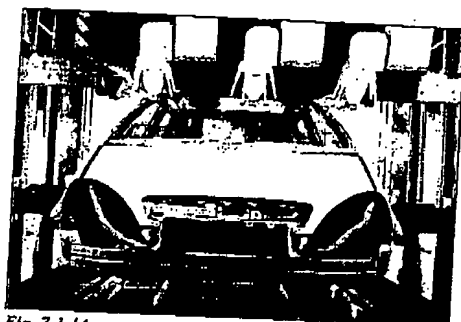


Fig. 7.1.14

Application of automotive top coats with high rotational bells and external electrodes for charging

manually there is no need for the "stop and go" mode.

Owing to the low solids content of effect coatings two applications are necessary at line speeds of about 3 m/min upwards. In the case of solid-color coatings there is usually only one application with electrostatic high rotation bells on account of the higher solids content.

In the case of effect coatings the first coat is also usually applied with electrostatic high rotation bells whilst the second coat is often still applied pneumatically with about 30% of the necessary quantity of

paint in order to achieve the desirable high effect in the orientation of the flake pigments and create easy reparability. To increase the efficiency of application and reduce costs high rotation bells, so-called micro-bells, are also being used nowadays for the second layer of basecoat. That achieves an effect in the coating which comes very close to that of pneumatic atomization.

Owing to the high conductivity of aqueous paints and on account of the many colors, usually more than 12, the electrostatic charging is performed with external electrodes. It helps to avoid elaborate isolation of the paint supply of the large number of many colors. However, development of the "cartridge" system is so far advanced that even direct charging systems whose technical arrangement has a perfect command of electrical isolation are used in production (see chapter 4.2.1).

The arrangement of the bells is usually selected in such a way that first of all the sides of the vehicle bodies are coated and only then does the roof machine start up. Both types of machine are capable of following the contours of the vehicle bodies within certain limits. Since the spray jet does not have a homogeneous material distribution, the roof machine performs motions at right angles to movement of the vehicle body in order to provide the coats with greater uniformity (see chapter 4.2.1).

Between the two application stages of effect coating there is a brief flash-off time of about 1 to 2 minutes. The purpose of this is to prevent the first coat from starting to dissolve, as a result of which the orientation of the effect particles is not lost. This is particularly important in order to ensure reliable reproducibility of the flop effects and the associated color perceived. The general rule is that the basecoat layers subjected to intermediate drying should have a residual water content of less than 10%.

When formulating such basecoats maximum flexibility should be obtained by optimizing the composition of all the paint components in order to guarantee a uniform color perceived in relation to application conditions. Owing to vehicle body shapes there are different distances and overlaps of spray jets. In the case of colors which are not very robust there are significant differences in color perceived and effect on a single vehicle body.

Effect paints for a paints with bright and color flop pain. The colors perceive physical principles: precision of the p create a light-dark or more oxide coat dependent color on Pearlescent effect p natural mother of p permit a whole host. For the necessary specification optica Nevertheless, owing and dependence or manufacturer's (see

Clearcoats

After application of drying zone, so-called application exerts of basecoats. Usually 3 - 5 minutes. As is speed up heating and not the vehicle body. The clearcoats chiefly borne bases, which the two components just before atomization 130 °C - 150 °C to c. One-component clear resin-based and they. The baking condition. The film thicknesses and appearance of the thicknesses on the ver requirements for ensu horizontal surfaces (pseudoplastic behavior applied reliably. This special resin combination. The one-component a high solid systems the; in North America by of paint components (see

Effect paints for automotive coating may be divided up into classes of metal effect paints with brightness flop, pearlescent effect paints with slightly changing color flop and color flop paints with a considerable color change.

The colors perceived, which are dependent on the angle of viewing, are created by two physical principles. Metal effect paints reflect the incident light depending on the precision of the positions of the aluminium flakes more or less efficiently and thus create a light-dark effect. Color flop paints require flakes which are provided with two or more oxide coatings with a varying refractive index. This then creates an angle-dependent color on account of interference caused by certain wavelength components. Pearlescent effect paints have less effect, which comes about in a similar way to that of natural mother of pearl (see chapter 2.1.3). The combinations of all pigment classes permit a whole host of new colors perceived (see chapter 3.2.4).

For the necessary quality control and for maximum precision when defining the specification optical multiangle measuring instruments are meanwhile state of the art. Nevertheless, owing to the problems already described due to the shape of vehicle bodies and dependence on application, visual inspection is still performed at the vehicle manufacturer's (see chapter 3.2.4).

Clearcoats

After application of basecoats the vehicle body passes through a short intermediate drying zone, so-called "flash off". The conditions are such that downline clearcoat application exerts no influence or only a minimal influence on color and effects of basecoats. Usually the parameters are as follows: 50 – 70 °C object temperature for 3 – 5 minutes. As is the case in most drying zones, infrared lamps are also used here to speed up heating and shorten the zones. Infrared lamps essentially heat up the coating and not the vehicle body so the cooling zones can also be smaller (see chapter 4.3.1). The clearcoats chiefly and increasingly used nowadays are two-component acrylic resin-borne bases, which are cured with polyisocyanates (see chapter 2.1.1). The mixing of the two components in the proportion of 3:1 to 5:1 is performed in the gun or bell just before atomization. Together with the dried basecoat curing is performed at about 130 °C – 150 °C to create a durable film.

One-component clearcoats used in addition to the two-component ones are also acrylic resin-based and they contain melamine resins or blocked isocyanates as cross-linkers. The baking conditions are comparable with those for 2-component clearcoats.

The film thicknesses are 40 to 50 µm. They are crucial for the brilliance, smoothness and appearance of the coating applied. In particular, it is important to observe the film thicknesses on the vertical surfaces without tendency to sag. This is one of the important requirements for ensuring that the difference in orange peel is not too large between the horizontal surfaces (small) and vertical surfaces (large). Thixotropic agent or specific pseudoplastic behaviour constitute the formulation bases for clearcoats which can be applied reliably. This viscosity characteristic is achieved either with additives or with special resin combinations (see chapter 2.1.4).

The one-component and two-component types of paint are dissolved in solvent and as high solid systems they can reach a solids content of up to 65%, as achieved particularly in North America by optimising the resins and improving the dissolving power of all the paint components (see chapter 5.6.1). The North American coatings industry has been

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Industry

		North America	Europe
2-component clear coats	NV	65 %	55 %
	VOC	250 g/l	350 g/l
1-component clear coats	NV	80 %	50 %
	VOC	300 g/l	420 g/l
VOC = volatile organic compounds			

Fig. 7.1.15
Solid content (NV) and VOC-numbers of actual clear coats

addressing the development of such high solids paints for approx. 25 years. For this purpose the molecular weight of the base resins and crosslinkers has been reduced by polymerization technology to such an extent that paint formulations with relatively high solids but identical viscosity can be achieved. The same applies to polyisocyanates and melamine crosslinkers.

The European coatings industry and paint-applying automotive industry decided in favour of aqueous basecoats and thus initially invested in flexibility in terms of application reliability, performance profile and emission of clearcoats. Owing to a self-commitment and legal conditions also being tightened up, users of solventborne clearcoats are now being forced to make a move. Aqueous, solvent-free products such as slurry and powder have found their first applications [7.12.13, 7.12.14].

The large film thicknesses of powder clearcoats from 60 – 80 µm provide a visible enhancement in the appearance of surfaces because they can create a so-called "wet look". What is meant by this is a deep gloss intensifying the color perceived which is revealed provided the surface is sufficiently smooth.

Slurry technology provides a dispersion of very small particles in water without solvent. This product makes it possible to utilize conventional material metering systems for liquids and also achieves thinner film thicknesses than with "dry" powder (see chapter 5.6.3).

Color trends

The impression which a vehicle makes on a potential buyer is very heavily dependent on color styling. For this reason the design departments of the automotive industry keep

Coating Industry

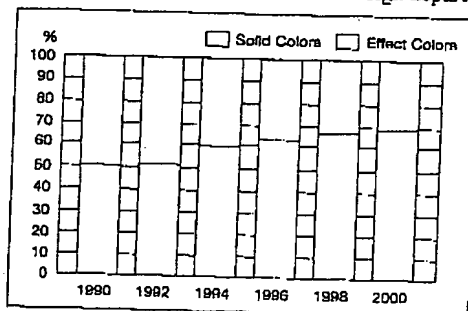


Fig. 7.1.16
Trends of effect colors for automobiles

a very close eye on trends in fashion, culture, art, furniture and social developments. At the same time they are in close contact with the paints and coatings industry in order to keep abreast of new possibilities for color and effect styling. So on the one hand colors follow trends in taste and on the other ideas for new color effects have to be heeded in order to achieve a stronger differentiation in the market and an increase in the attractiveness of vehicles.

which have been dra last few years there colors are black and is most evident in I emphasize the chara All in all, when a bu from, provided he is "tie colors", which r to the customer's wi

7.1.6 Repair

Despite all precautio such as dirt conta completely avoided. coated vehicle body special illumination trained member of st Minor defects, espec remedied by sanding for either a spot req whereby the vehicle ingly, usually with through the entire coa The spot repair of r conducted manually booths. With special r are prepared by skilfu. cutting out and then special spraying units ular problem. The OE this purpose. The nece ature is created locall point of repair. This n high level of manual application units and one hour. It means the repair over a larger arc When a whole body r coating process a secc Normally the total coa Apart from the surface objective quality patter ness, gloss, haze and s able measuring instrum control. These measu:

Generally speaking, it is important not to exceed a total film thickness of 100 μm in the refinish system.

7.3 Automotive Supply Industry

Over the last few years the automotive supply industry has gained considerable importance. Worldwide turnover came to 350 billion euros in 1999. This is due to the global strategy of the automotive manufacturers endeavouring to reduce the production depths of their products (cars) and shift the development of components and their assembly to the supply industry. Production depths in German car manufacture, for example, were only about 30% in the year 2000. In the USA GM and Ford have divested themselves of their subsidiaries Delphi and Visteon. At the same time the number of direct suppliers has fallen drastically so a pyramid of first, second and third tier suppliers has formed for the automotive industry. The wave of consolidation which thus took place at the end of the 1990s has nowadays led to large global suppliers with turnovers of up to more than 50 billion euros.

The diversity of products in this industrial segment is enormous. It has bound to lead to the fact that practically all coating processes are used. For example, there is the entire range of eco-efficient processes such as powder coating, electrocoating and coating processes based on radiation curable paints. The use of new application techniques and coating materials often begins in that market segment.

The industry can be divided up into the following segments:

- Exterior plastic attachments
- Interior plastic attachments
- Wheels
- Axles
- Engine blocks
- Mirrors
- Head lamps
- Door handles
- Other parts

Exterior plastic attachments

The most important plastic attachments for the exterior on all car models nowadays include the bumpers, which are moulded from a very wide variety of thermoplastics but are coated predominantly. There are also tailgates, such mainly PP lids, sliding roofs, fenders, trims and outer mirrors, which are already coated when delivered because they are fitted to the vehicle body later. Furthermore, these attachments such as the outside mirrors are put together as assemblies with all the electrical equipment so they can no longer be coated at the car plant [7.12.23].

Since there have to be further reductions in weight and cost the trend towards using plastics continues to be on the increase.

The plastics used are primarily tailored to the necessary functionality on the vehicle body. Consequently most bumpers are made of highly flexible, impact-resistant and low-cost polypropylene (PP) blends.

The coating of these parts is performed on specially designed coating lines. On many lines throughout Europe the procedure initially provides for aqueous cleaning in the "power wash" process, then flaming in order to improve adhesion, an aqueous priming followed by application of aqueous basecoats and solventborne 2-component clearcoats. Between the primer and topcoat application there is a short intermediate drying process.

which takes 2 to 3 minutes. The crosslinking temperatures are 80 – 90 °C and they require dedicated paints for primer and clearcoat application. The trend towards eliminating primer is on the increase because owing to flaming there is no longer any need for special-purpose, adhesion primers. Moreover, the cost advantages achieved by eliminating a coating stage are significant. In North America and Asia flaming is often replaced by applying an adhesion primer (promoter), which is usually formulated with chlorinated polyolefins [7.12.24]. The crosslinking temperatures are then slightly higher at approx. 120 °C. Aqueous products are still not very common in those regions.

On many coating lines application is performed by robots and pneumatic spray guns, which achieve a maximum transfer efficiency of 40%. For an electrostatically assisted coating plastics have the crucial disadvantage that they are usually nonconductive. This



Fig. 7.3.1
Coating of bumpers

can lead to the fact that electrostatic charges on the workpiece repel the charged paint and affect the quality of the coating. This disadvantage can be eliminated if conductive primers are used. With good grounding and use of electrostatically assisted high rotation atomizers good results are achieved in the downline application of basecoat and clearcoat [7.12.25]. On account of the high conductivity of aqueous paints the charging is performed after spraying by means of external electrodes

(see chapter 4.2.1). The levels of transfer efficiency for the coating materials reach 60% – 70% under the conditions described.

The efficiency of the coating lines, measured by first time capability, is not as good as in automotive OEM coating because owing to the low conductivity of the plastics there is a risk of electrostatic charge effects. As a result, particles of dirt are attracted. Efficiencies of 60% – 70% are good levels for a coating line handling plastic parts. The low material and production costs for bumpers mean that it is not necessary everywhere to rework all defective parts. In addition, production of new parts is less expensive and it is easy to recycle the thermoplastics [7.12.26].

The definition of a color specification with respect to visual or colorimetric aspects is firstly important for the success of the supplier. Secondly, the ability to make corrections for coating bumpers quickly is necessary because first-time body coating color discrepancies can occur or the coating does not conform to the specification of the color. Different concepts provide for parallel, harmonized paint development and production as well as an intensive exchange of test results and empirical results [7.12.27].

Furthermore, the coating of plastics may only have a minimum negative influence on the mechanical properties of the substrate (e.g. impact resistance at –30 °C). For this reason the paints used in automotive production coating are not always suitable for

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plastic coating. In particular, the primer surfacers and clearcoats for plastic coatings are formulated with highly flexible resins and isocyanate crosslinkers. Nevertheless, it has so far not always been possible to ensure that on account of the crosslinked coating properties such as impact resistance of the plastic at low temperatures in particular are not affected.

Fenders are made of a very wide variety of plastic blends, depending on the specification requirements made by the vehicle manufacturers. Usually they are merely primed at the manufacturer's and then coated on the respective vehicle manufacturer's production coating line after electrocoating. The reason for this is that it is possible to achieve a much higher level of integration for mounting the attachment in the vehicle body assembled from the various materials. The fenders not made of thermoplastic polyolefins (TPO) such as polyamide merely require good surface cleaning, e.g. with a "power wash" process, so that they can then be coated with a primer. The same applies to the outer skin of the tailgates to be coated, which, on account of the rigidity requirements of such an attachment, are increasingly being made of "sheet moulding compounds" (SMC), e.g. based on unsaturated polyesters (see chapter 4.1.3).

Interior automotive attachments

In order to upgrade interior plastic mouldings or the housing of the dashboard as well as many other parts in the passenger compartment of vehicles coating is required in many cases if low-cost plastics are used. The coating is such that the layer of paint not only improves the surface visually but also creates a certain amount of grip (feel). In English-speaking countries such coating materials are termed "soft feel" coatings.

Such modern coatings are mainly applied with 2-component, polyurethane-based systems which are also available in the aqueous form. The latter are starting to become more common. With the usual film thicknesses of 20 – 40 µm highly specific requirements are also fulfilled, e.g. laser engravability, low surface reflection in the form of "velvet" coatings, high flexibility at low temperatures, e.g. in the case of airbags, the triggering of which has to take place at low temperatures without creating any splinters. The avoidance of emissions from the plastic parts is also included.

Most recently colored coatings have been used in order to following fashion trends for small vehicles. All in all, this market is growing very significantly because with this coating the acceptance of plastic as a material is considerably enhanced and helps to avoid the "cheap" image [7.12.28]. Application is performed on lines similar to those used for exterior coating. However, for the plastics chiefly used in this segment, e.g. PA, PC, ABS, polybutylene tere-



Fig. 7.3.2
Different coated plastic parts inside of a car

Coating
Industry

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